1B04/52167

Europäisches Patentamt | European Patent Office | Office européen des brevets

MAILED 28 OCT 2004
WIPO PCT

Bescheinigung | Certificate | Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. Patent application No. Demande de brevet n°

03104079.3

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

Anmeldung Nr:
Application no.: 03104079.3
Demande no:

Anmeldetag:
Date of filing: 05.11.03
Date de dépôt:

Anmelder/Applicant(s)/Demandeur(s):

Koninklijke Philips Electronics N.V.
Groenewoudseweg 1
5621 BA Eindhoven
PAYS-BAS

Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

A MRI system having reduced acoustic noise

In Anspruch genommene Prioriät(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/
Classification internationale des brevets:

G01R33/20

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of filing/Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LU MC NL
PT RO SE SI SK TR LI

A MRI system having reduced acoustic noise

The invention is related to a magnetic resonance imaging (MRI) system including a gradient coil system comprising an inner coil configuration, and an outer coil configuration being positioned substantially coaxially to said inner coil configuration, both coil configurations being attached to a tubular body located between said two coil configurations and extending substantially coaxially to both said coil configurations.

In such a system the tubular body has two functions. At the one hand it connects the two coil configurations to form a rigid tubular gradient coil system, and at the other hand it keeps the inner coil configuration at the required distance from the outer coil configuration. The complete gradient coil system has a substantially tubular shape and encloses the measuring space of the MRI system.

US-A-6147494 discloses such MRI system, comprising a superconductive coil system for generating a steady magnetic field in the Z-direction, i.e. the axial direction, of a measuring space of the apparatus, whereby the gradient coil system is arranged within said superconductive coil system. The gradient coil system also serves to generate a magnetic field in the measuring space of the apparatus. Thereby the inner coil configuration generates a gradient field and the outer coil configuration is an enclosing shielding coil for shielding the environment from the gradient field generated by the inner coil configuration. Between the inner coil configuration and the outer coil configuration there is a tubular body connecting both said coil configurations. The tubular body is made from synthetic material such as fiberglass-reinforced epoxy.

During operation of such MRI system acoustic noise is generated because of vibrations in parts of the system. These vibrations are caused by changing (alternating) Lorentz forces exerted on the different parts of the system. Such noise is annoying for the person lying in the system as well as for the operators of the system. Although there have been many attempts to decrease the level of noise generated by the MRI system in operation, in the existing systems there is still an annoying noise level.

The object of the invention is to decrease the noise level during operation of the MRI system considerably.

In order to accomplish that objective, said tubular body between said inner coil figuration and said outer coil figuration comprises stainless steel rods, substantially positioned in axial direction of the tubular body. Such stainless steel rods reduce the flexibility of the tubular body. Especially, it increases the resistance against bending of the tubular body. The rods may have any dimension, but their cross section should not be too large to avoid much eddy current. The stainless steel rods can be embedded in the material of the tubular body, being for example epoxy comprising glass spheres and/or epoxy reinforced with fiberglass.

The expression "stainless steel rod" includes any oblong piece or assembly of stainless steel, also for example a stainless steel cable.

In practice it has appeared that vibrations in the system can be considerably reduced by increasing the resistance of the tubular body against bending, and that such resistance can effectively obtained by application of said stainless steel rods in the material of the tubular body.

Preferably, the stainless steel rods are present in the central portion of the tubular body, i.e. near the radial plane in the middle of the tubular body. At that location the forces in axial direction in the material of the tubular body are relative large, which forces tend to bend the tubular body. Therefore it is effective to reinforce the tubular body especially at that location.

In one preferred embodiment, the stainless steel rods substantially extend over the entire length of said tubular body, providing for reinforcement of the whole tubular body. Preferably, the stainless steel rods are connected to each other at both ends of each rod. Thereby the rods are effectively attached to each other to form an assembly of rods, in order to obtain a correct mutual positioning of the rods in the material of the tubular body.

In one preferred embodiment, said tubular body comprises a stainless steel cylindrical wall having axial slits to form the axial directed rods. After a stainless steel cylindrical wall is formed, the wall can be provided with axial directed slits by a material removing operation, for example by means of a laser beam, in order to form the assembly of stainless steel rods.

In another preferred embodiment said stainless steel rods are strips substantially positioned in a cylindrical surface. The expression strip means a rod having a

rectangular cross section, whereby the longer side is much longer than the relative small shorter side. The shorter side can be between 0.5 mm and 3 mm, preferably between 1 mm and 2 mm. The longer side of the rectangular shape of said cross section can be between 5 mm and 40 mm, preferably between 10 mm and 25 mm.

To form the cylindrical surface of strips (in fact a cylindrical wall, whereby the strips may overlap each other), a plate-like element can be wound into a spiral shape by means of a mandrel in order to form the cylindrical wall, whereby said plate like element comprises substantial parallel stainless steel strips, and whereby the stainless strips extend in substantial axial direction after the cylindrical surface is formed. The cylindrical wall is composed of one or more layers of the plate-like element, whereby the turns of the plate-like element are electrically insulated with respect to each other. In order to achieve such insulation, a layer of insulating material can be present between the turns of the plate-like element. The insulation can also be obtained by composing the plate-like element of two layers, being a layer of insulating material and a layer comprising the stainless steel strips. Furthermore, the space between the strips in the plate-like element can be filled up with electrically insulating material.

In one preferred embodiment, at least some of said rods comprise cooling channels for guiding a cooling fluid. In case the gradient coil system has to be cooled by means of a cooling medium, for example water, it is efficient to accommodate cooling channels in the stainless steel rods, because stainless steel is a good material for guiding heat.

In one preferred embodiment, at least some of said rods comprise an axially extending space accommodating pieces of shim iron. Such pieces of iron can be mounted on a plastic shim rail, and the shim rail can be shifted into said space. The pieces of shim iron serve to achieve further homogenization of the steady magnetic field which is generated by a coil system surrounding the gradient coil system.

The invention will now be further elucidated by means of a description of some embodiments of a gradient coil system of a MRI system, whereby reference is made to the drawing comprising figures which are only schematic representations, in which:

Fig. 1 is a portion of a sectional view of a gradient coil system according to the prior art;

Fig. 2 is a corresponding view showing a first embodiment of a gradient coil system according to the invention;

Fig. 3 is a side view of an assembly of rods as applied in the first embodiment;

Fig. 4 is a front view of the assembly of rods shown in figure 3;

Fig. 5 shows a second embodiment of a gradient coil system;

Fig. 6 shows a wound plate-like element;

Fig. 7 shows a third embodiment of a gradient coil system;

Fig. 8 shows a fourth embodiment of a gradient coil system;

Fig. 9 shows a fifth embodiment of a gradient coil system; and

Fig. 10 shows a sixth embodiment of a gradient coil system;

In the different embodiments, corresponding parts are indicated with the same reference numerals.

Figure 1 shows a portion of a sectional view of a gradient coil system forming part of a MRI system according to the invention. The other parts of the MRI system are not shown in the figures, as these parts are all well known to the person skilled in the art. The complete gradient coil system has a substantial tubular shape, and its dimension is such that a person, or at least the main part of a person, can be accommodated inside the tubular system (in the measuring space), so that the human body, or a part of the human body, can be investigated by the system. A sectional view in a radial plane has an annular shape. A portion of that annular shape is represented in figure 1, and also in the figures 2, 5, 7, 8, 9 and 10. In fact, such portion of the sectional view represents the configuration of the complete gradient coil system. In general, the system is located in a superconductive coil system generating a steady magnetic field in said measuring space in the Z-direction (axial direction) of the tubular gradient coil system. The gradient coil system provides for a gradient of the magnetic field in certain directions.

According to figure 1, an inner coil configuration comprises three layers 1,2,3 located at the inner side of the gradient coil system. Each layer comprises coils for generating a magnetic field gradient in a certain direction. Layer 1 generates a magnetic gradient in Z-direction, i.e. the axial direction of the tubular gradient coil system. Layer 2 generates a magnetic gradient in X-direction, i.e. a radial direction perpendicular to the Z-direction, and layer 3 generates a magnetic gradient in Y-direction, i.e. the direction perpendicular to the X-direction as well as perpendicular to the Z-direction. Therefore, layer 1 comprises coils substantially in radial planes, so that the coils run around the measuring space in the tubular gradient coil system. Layers 2 and 3 comprise saddle-shaped coils. Such a saddle-shaped coil

extends in the layer 2 and in the layer 3 at one side of a plane through the axis of the tubular gradient coil system.

The outer coil configuration is located at the outer side of the gradient coil system and comprises also three layers 4,5,6. Layer 4 comprises coils for generating a magnetic field gradient in the Z-direction, which coils are substantially located in radial planes, like the coils in layer 1 of the inner coil configuration. Layers 5 and 6 comprise saddle-like coils to generate magnetic field gradients in the X-direction and the Y-direction respectively.

As shown in figure 1, a tubular body 7 is present between the inner coil configuration 1,2,3 and the outer coil configuration 4,5,6. The material of the tubular body 7 is epoxy containing glass. At the inner side 8 the epoxy contains glass spheres as filler, and at the outer side 9 the epoxy is reinforced by glass fibers. The tubular body 7 connects the inner coil configuration 1,2,3 with the outer coil configuration 4,5,6, and furthermore the tubular body 7 keeps the two coil configurations 1,2,3 and 4,5,6 at the required distance from each other.

Figure 2 shows a first embodiment of the gradient coil system according to the invention, whereby the tubular body 7 comprises stainless steel rods 10, substantially having a rectangular cross section. The stainless steel rods 10 are located at the outer side of the tubular body 7 (near the outer coil configuration 4,5,6), but the rods 10 may also be located at the inner side (near the inner coil configuration 1,2,3) or somewhere in the middle area. The remainder of the tubular body 7 comprises epoxy with glass spheres, indicated with 11. That material is also present between the stainless steel rods 10.

Figure 3 shows a stainless steel cylindrical wall 12 in side view, and figure 4 shows the same cylindrical wall 12 in front view, i.e. in axial direction. In this example of an embodiment, the thickness of the cylindrical wall 12 is about 10 mm, the length is about 1.2 m, and its diameter is about 50 cm. The cylindrical wall 12 is provided with slits 13 in axial direction. The distance between the slits 13 is about 15 mm. Each slit 13 has a width of about 1 mm, and extend in a plane through the axial axis of the cylindrical wall 12. The slits 13 terminate at a short distance from the edge 14 of the cylindrical wall 12.

The cylindrical wall 12 provided with slits 13 as shown in figures 3 and 4 form an assembly of parallel stainless steel rods 10, whereby a rod 10 is present between each pair of neighboring slits 13. The assembly of rods 10 is used to produce the first embodiment of the gradient coil system as shown in figure 2. The assembly of parallel rods 10, whereby the rods are interconnected at both ends, i.e. near the edge 14, forms a stable framework of the

tubular body 7. After it is placed and positioned between the inner coil configuration 1,2,3 and the outer coil configuration 4,5,6, the epoxy 11 containing glass spheres can be applied, so that a massive and stiff tubular gradient coil system is obtained.

Figure 5 shows a second embodiment of the gradient coil system. In this embodiment the stainless steel rods 10 are strips, whereby the longer side of the rectangular cross section of each rod 10 is much longer than the shorter side. The stainless steel rods 10 are arranged in three layers and electrical insulating material is present between the rods 10, which material can be epoxy, which may contain glass spheres.

The assembly of strip-like stainless steel rods 10 comprising the three layers of rods 10 can be manufactured by winding a plate-like element 15 around a mandrel in order to form a spirally wound cylindrical wall 16, as is shown in figure 6. Thereby the plate-like element 15 comprises stainless steel strips in a direction perpendicular to the direction of bending the plate-like element 15. The strips may be interconnected at their ends, in order to ensure a correct parallel positioning of the strips.

The space between the strips in the plate-like element 15 can be filled up with insulating material. Furthermore the plate-like element 15 can be provided with a layer of insulating material at one side, so that the insulating material is present between the strips - or rods 10 - after the plate-like element is wound to form the cylindrical wall 16. In the second embodiment, as shown in figure 5, there are three layers of strip-like stainless steel rods 10 present, but the number of layers can be much higher.

Figure 7 shows a third embodiment of a gradient coil system, whereby the stainless steel rods 10 has a Z-shaped cross section. The rods 10 are arranged in a stacking position, whereby they overlap each other partly. Such configuration of the stainless steel rods 10 provides a very stable assembly of rods 10.

Figure 8 shows a fourth embodiment, whereby the stainless steel rods 10 are provided with a cooling channel 18 for guiding a cooling fluid like water. Because the material of the rods 10 is a good guide for heat, an efficient heat transfer to the cooling fluid is ensured.

In the fifth embodiment of the gradient coil system, shown in figure 9, there is not only a cooling channel 18 present in the stainless steel rods 10, but also a space 19 to accommodate a shim rail. The shim rail is not shown in the figure, because it is a known device. It is a plastic rail and pieces iron can be attached to it. The presence of the pieces serve to achieve homogenization of the steady magnetic field which is generated by a coil system surrounding the gradient coil system.

Figure 10 shows a sixth embodiment corresponding to the embodiment shown in figure 9, however, the stainless steel rods 10, containing the cooling channels 18 and the space 19 for the shim rail, extend over a major portion of the tubular body 7. Thereby the stainless steel rods 10 are located near both gradient coil configurations 1,2,3 and 4,5,6, whereby both configurations are effectively cooled.

CLAIMS:

1. A magnetic resonance imaging system including a gradient coil system comprising an inner coil configuration (1,2,3), and an outer coil configuration (4,5,6) being positioned substantially coaxially to said inner coil configuration, both coil configurations (1,2,3;4,5,6) being attached to a tubular body (7) located between said two coil configurations and extending substantially coaxially to both said coil configurations, characterized in that said tubular body (7) comprises stainless steel rods (10) substantially positioned in axial direction.

2. A system as claimed in claim 1, characterized in that stainless steel rods (10) are present in the central portion of the tubular body (7).

3. A system as claimed in any one of the preceding claims, characterized in that stainless steel rods (10) substantially extend over the entire length of said tubular body (7).

4. A system as claimed in any one of the preceding claims, characterized in that said stainless steel rods (10) are connected to each other at both ends (14) of each rod (10).

5. A system as claimed in any one of the preceding claims, characterized in that said tubular body (7) comprises a stainless steel cylindrical wall (12) having axial slits (13).

6. A system as claimed in any one of the preceding claims, characterized in that said stainless steel rods (10) are strips substantially positioned in a cylindrical surface (12,16).

7. A system as claimed in any one of the preceding claims, characterized in that a plate-like element (15) is wound into a spiral shape in order to form a cylindrical wall (16), whereby said plate-like element (15) comprises substantial parallel stainless strips, the stainless strips extending in substantial axial direction after the cylindrical wall (16) is formed.

8. A system as claimed in any one of the preceding claims, characterized in that at least some of said rods (10) comprise cooling channels (18) for guiding a cooling medium.

9. A system as claimed in any one of the preceding claims, characterized in that at least some of said rods (10) comprise an axially extending space (19) accommodating pieces of shim iron.

ABSTRACT:

A magnetic resonance imaging (MRI) system including a gradient coil system. The gradient coil system comprises an inner coil configuration (1,2,3), and an outer coil configuration (4,5,6) being positioned substantially coaxially to said inner coil configuration (1,2,3). Both coil configurations are attached to a tubular body (7) located between said two coil configurations (1,2,3;4,5,6) and extending substantially coaxially to both said coil configurations. The tubular body (7) comprises stainless steel rods (10) substantially positioned in axial direction.

Fig. 2

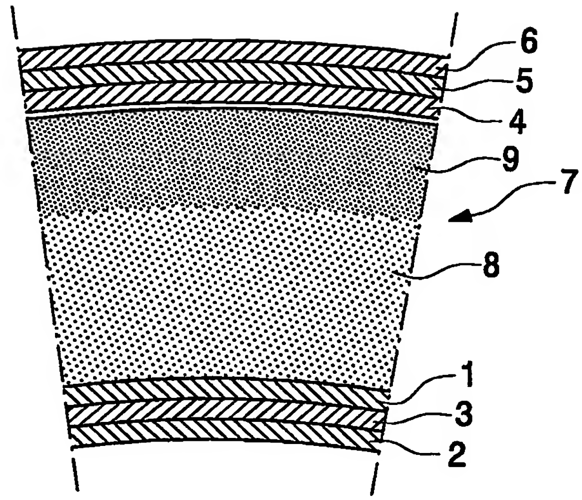

Fig.1

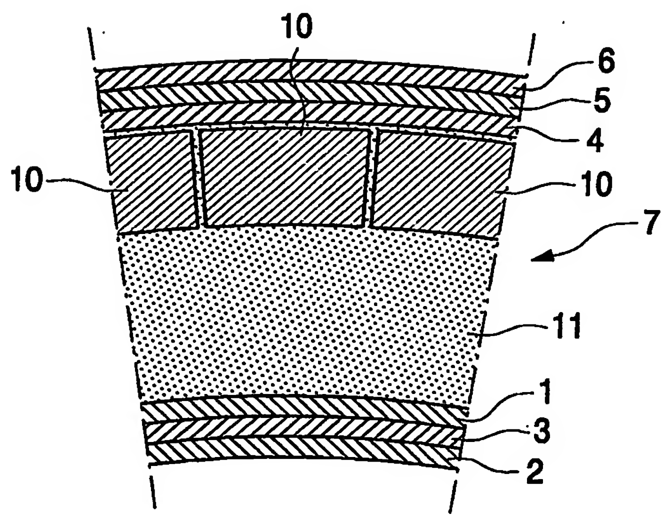

Fig.2

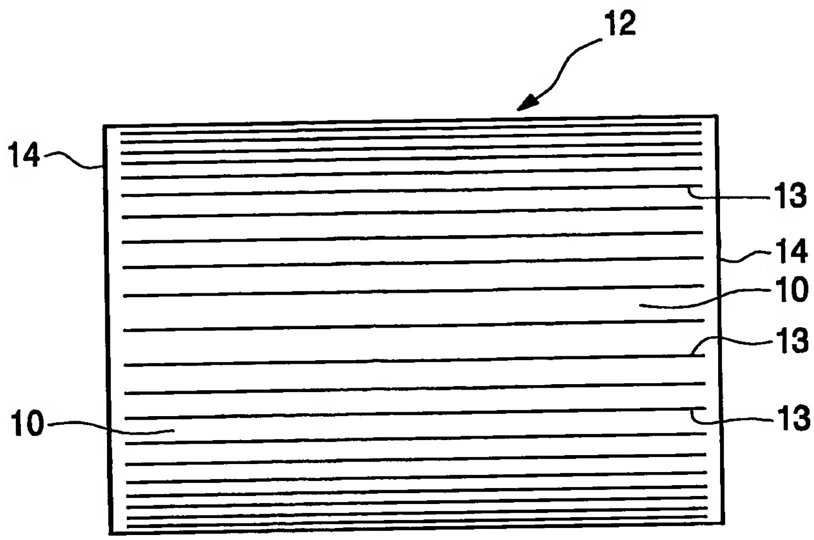

Fig.3

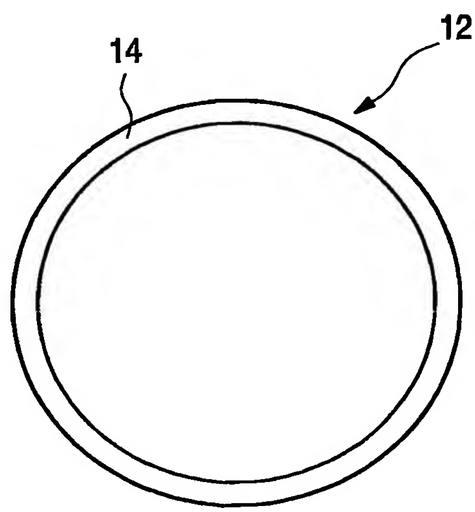

Fig.4

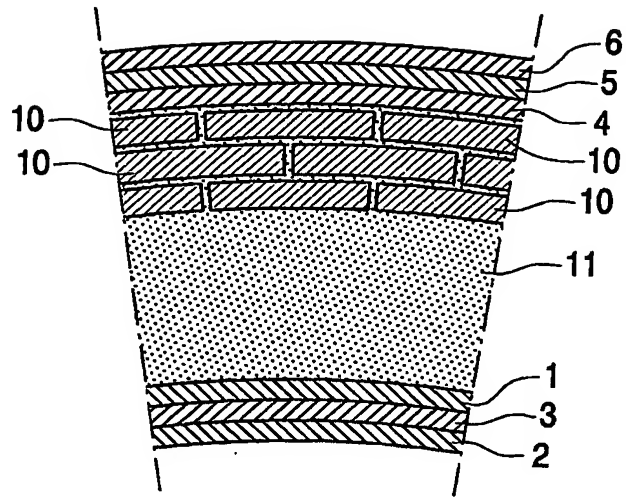

Fig.5

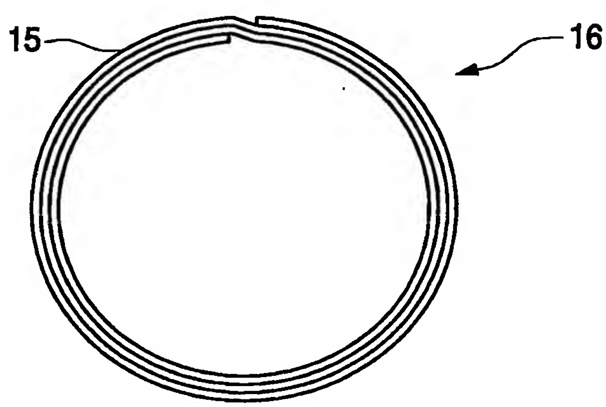

Fig.6

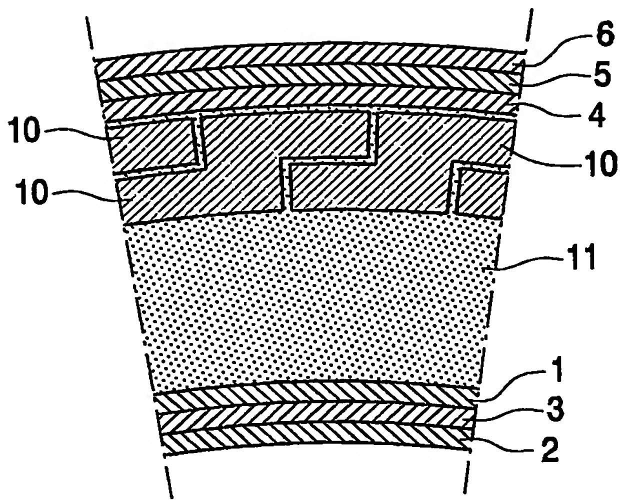

Fig.7

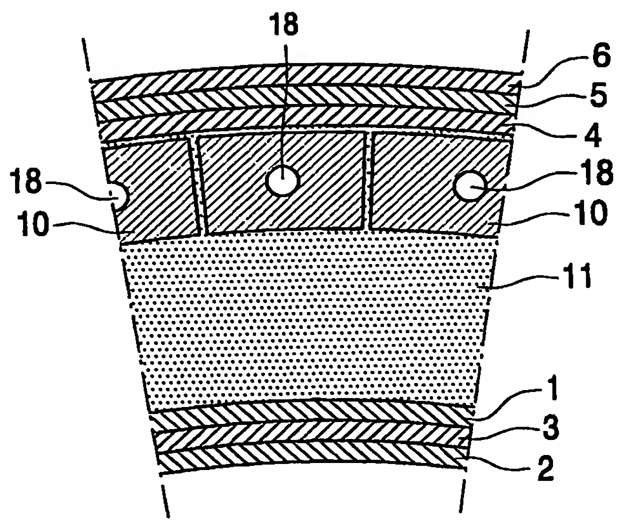

Fig.8

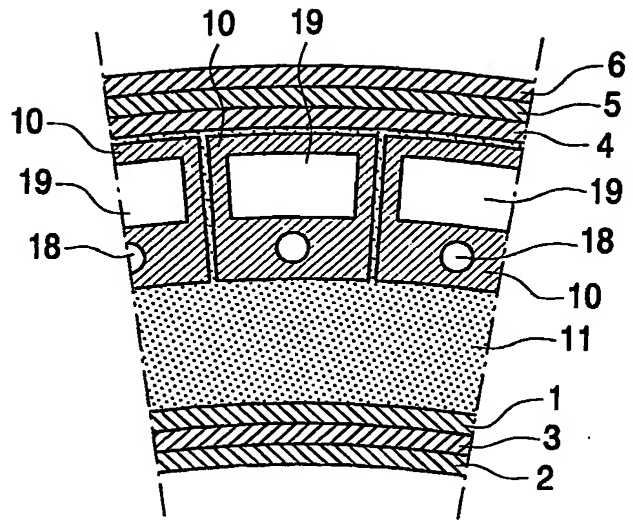

Fig.9

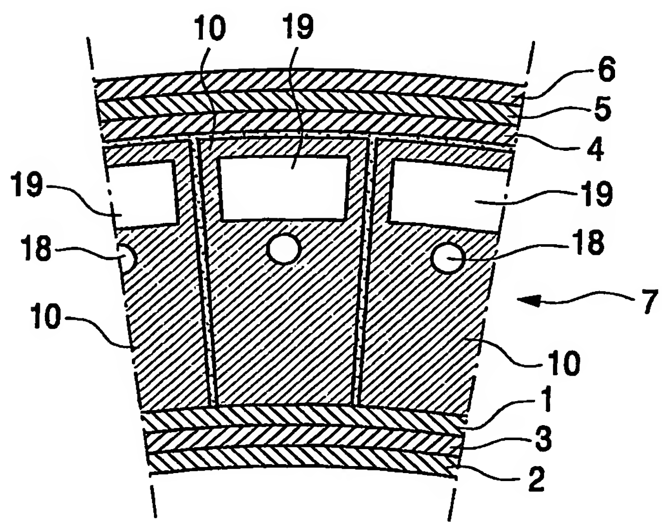

Fig.10